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### Publication Date

1960-12-29

*BL*

UCRL-9274

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Lawrence Radiation Laboratory  
Berkeley, California

Contract No. W-7405-eng-48

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Frank Evans and Frederick A. Kirsten

December 29, 1960

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### ABSTRACT

The logical design and organization of an 1800-bit buffer store for use with nuclear physics experiments is described. The heart of the system is an 1800-bit magnetic core memory, which stores up to 10 events, each event consisting of 180 parallel bits of input information. The storage time per event is 40 $\mu$ sec. Upon command the buffer store transfers the information out of the core memory, six parallel bits at a time, onto punched paper tape.

The buffer store uses transistorized circuits of modular design, constructed on printed boards, and interconnected by taper-pin wiring.

Further aspects of this system are discussed by S. C. Baker, F. A. Kirsten, D. A. Mack, and C. Wiegand in "An Electronic Data-Aquisition System for Use with a Complex Nuclear Physics Experiment," UCRL-9271, December 1960; by S. C. Baker in "A Transistor Coincidence-Discriminator Circuit for  $10^{-8}$ -Second Pulses," UCRL-9272, November 1960; by A. Bjerke, Q. A. Kerns, and T. Nunamaker in "A Solid-State Chronotron for Digitizing Time Delays," UCRL-9270, December 1960; by Q. A. Kerns and G. C. Cox in "A Nanosecond Triggered Light Source Using Field Emission," UCRL-9269, October 1960; and by S. C. Baker, Q. A. Kerns, F. A. Kirsten, D. A. Mack, and T. A. Nunamaker, "Test Routines and Monitoring for a Large Counter Experiment," UCRL-9273, December 1960.

# AN 1800-BIT BUFFER STORE AND READOUT SYSTEM\*

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## INTRODUCTION

In a complex experiment where it is necessary to transfer coordinate and time information from a nuclear event into a low-speed record, e. g. punched paper tape, a buffer store is usually interposed. This comparatively small store temporarily holds binary data from particle detectors, coincidence circuits, etc., preparatory to unloading in a uniform sequence. The data for each event is often presented simultaneously over many channels, and each event occurs randomly in time. The effect of the buffer store, then, is to average the acquisition rate with respect to the permanent tape record.

In the following discussion, we shall describe a system employed in Bevatron experiments having a large number of detectors. The buffer consists of magnetic-core memory elements, including the drive and control circuits. The end product is punched paper tape.

## MAGNETIC-CORE PLANES

The store is made up of six planes, each containing a 10-by-30 array of toroidal cores. The magnetic material is a ferrite having a nearly square hysteresis loop with the two residual flux states representing the binary numbers

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\*This work was done under the auspices of the U. S. Atomic Energy Commission.

0 and 1. Part of a plane is shown in Fig. 1. Each core is linked with two read wires, two write wires, and one sense wire. Coincident current pulses of equal magnitude on the two read wires threading a given core will return the residual flux to the 0 state. These currents are adjusted so that the magnetomotive force contributed by a pulse on one read wire is not great enough to reverse the flux. At the end of a read cycle all cores are in the 0 state.

Similarly, during the write cycle, binary 1's are entered by supplying two coincident currents of the polarity opposite to the read pulses at the selected core location.

The sense winding shown links all memory elements in the plane. A voltage pulse is induced on this wire whenever the flux in the core is reversed. The sense winding output is gated only during the read interval.

For the write mode, the 30 vertical write wires in each array--180 in all-- are connected separately. These correspond to the 180 binary input channels in this experiment. Of these channels, 168 contain coordinate data and the other 12 contain time information. In the horizontal direction, the wires are connected in series through all six planes. These ten circuits then are called event-write lines, each one of them containing one core from every data channel. The buffer store has a capacity of ten events, each with 180 descriptive bits.

The paper tape has seven levels. The first six are reserved for binary data, the seventh for odd parity write-in. The store then is unloaded in groups of six-bit characters. In the read mode the store is wired so that each core plane is unloaded into one tape level--one bit per character. The sequence of reading out is from top to bottom, with the events appearing on tape in the order of occurrence.

### FUNCTIONAL ARRANGEMENT

The functional diagram of the circuitry used with the core store is shown in Fig. 2. When an event is detected, a STORE EVENT command is fed into the store control, which in turn opens the gates on the 180 data channels. The gate outputs are fed into corresponding bit line drivers, which can be triggered by binary 1's but not by 0's. A counter advances with each event, and the event-write lines of the core store are energized in sequence.

Some events will not be stored. The store control will not open the data gates if (a) a previous event is being stored at the same time, (b) the contents of the store are being read out, or (c) the store is already filled to ten events. In the first case, an event following within less than 40 $\mu$ sec (the total storing time) will be lost. The store control also puts out a store-complete signal, which indicates that an event has been stored and that there are less than ten events in store.

A PUNCH command starts the sequence that unloads the entire store into paper tape. This is done at 60 characters per second, the maximum rate of the Teletype punch. The first three characters are fixed information including the Bevatron-pulse serial number. These are followed by one space, then 300 characters representing event data. The total readout time is approximately 5 sec. In Bevatron experiments, this permits unloading the store between beam pulses. If less than ten events are stored between beam pulses, only those portions that are filled will be read out. The punch-out time will be correspondingly less.

The read selectors shown in Fig. 2 select the core locations to be interrogated. With each tape character, the punch control advances the counter, which in turn operates the read selectors. Sense amplifiers detect the presence of 1's as pulses and fill the corresponding registers in the



punch-out circuits.

### CIRCUITRY

The store control, punch control, and part of the punch-out consist of logic circuits, i. e., flip-flops, one-shot multivibrators, "and" gates, "or" gates, and inverters. These are made up as standard transistor boards with two or more circuits per board.

The cores require 380 ma to reverse flux. A coincident current pulse of 190 ma is supplied by a blocking-oscillator circuit shown in Fig. 3. The voltage across D-1 normally biases off  $Q_2$ . When the trigger appears as shown, the collectors start toward +15v, current flows to the base of  $Q_2$  from  $T_1$ , and  $Q_2$  becomes regenerative. Unless the permissive gate appears on  $Q_1$ ,  $Q_2$  will not be triggered. Resistor  $R_4$  limits the current into the cores, and capacitor  $C_2$  limits the pulse rise time to prevent capacitive feed-through to the sense winding. The voltage backswing is prevented from exceeding the rating on the 2N315A by D-2.

Pulses appearing at the sense windings are coincident with the leading edge of the read current pulses, and are about 20 mv in amplitude for a binary 1, and 3 mv for a disturbed 1. The sense amplifier shown in Fig. 4 amplifies these pulses discriminating against those with amplitudes of 3 mv and less. The base of  $Q_1$  and collector of  $Q_2$  are grounded, thus amplifying pulses of either polarity. Transformer T2 and diodes D1 and D2 form a pulse rectifier, which in turn supplies only negative pulses to the noninverting amplifier  $Q_3$  and  $Q_4$ . Actually,  $Q_3$  is slightly below cutoff, and consequently discriminates against small pulses. A low impedance output is furnished by  $Q_5$ . The overall gain is about 1000, with the output limiting at -15v.

### CONCLUSIONS

The buffer is adequate for many experiments. Practically all of the events recorded to date have had very few binary ones in the 180 data channels. As a result, many more events could be stored in the same core planes, if the input data were coded.

### ACKNOWLEDGMENT

The authors wish to thank Messrs. D. A. Mack and J. A. G. Russell for their stimulating discussions and criticism during this development.

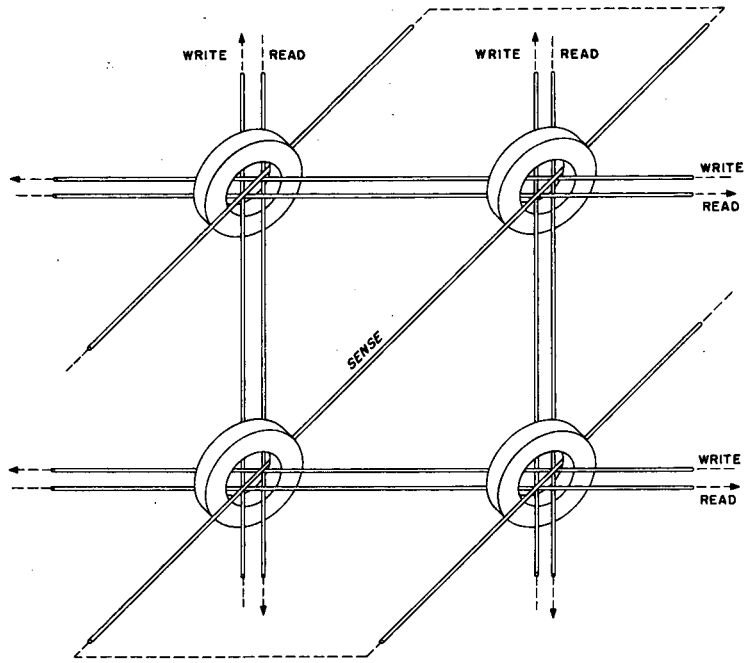
LEGENDS

Fig. 1. Part of core plane.

Fig. 2. Functional diagram of the buffer store.

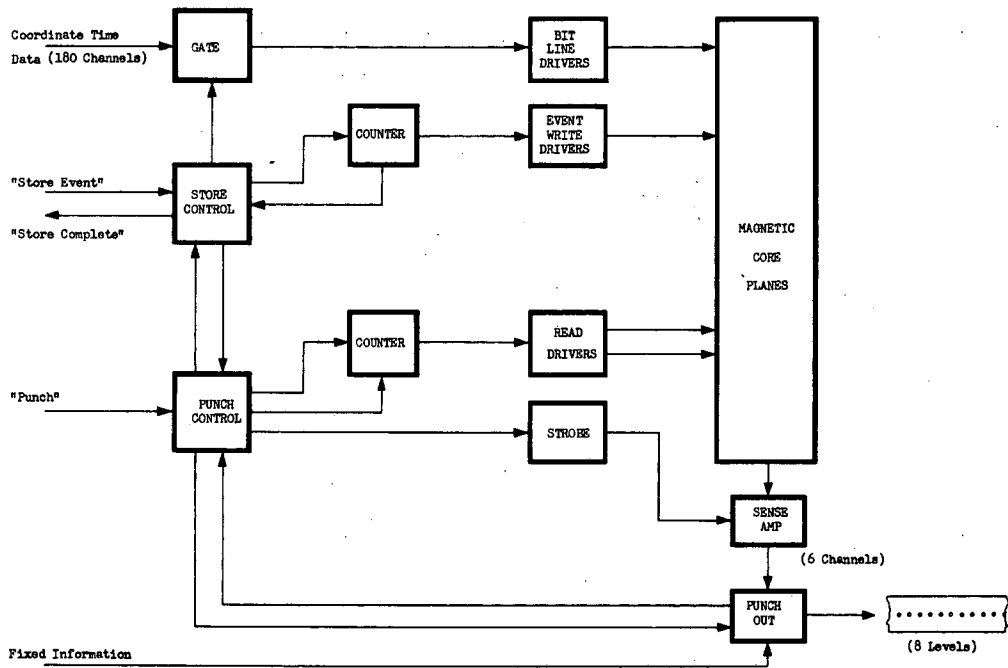
Fig. 3. Schematic diagram of the core driver.

Fig. 4. Schematic diagram of the sense amplifier.



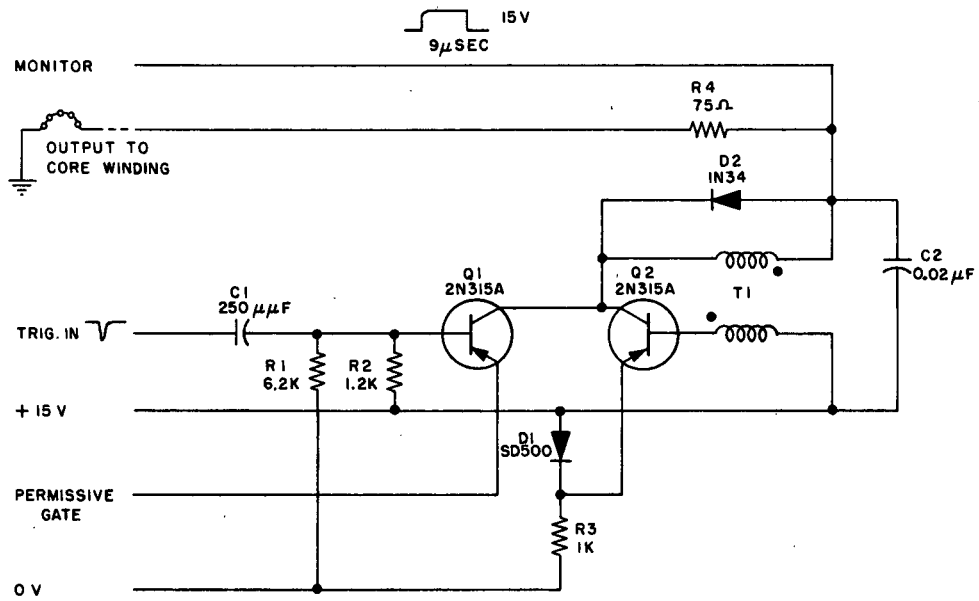
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Fig. 1.



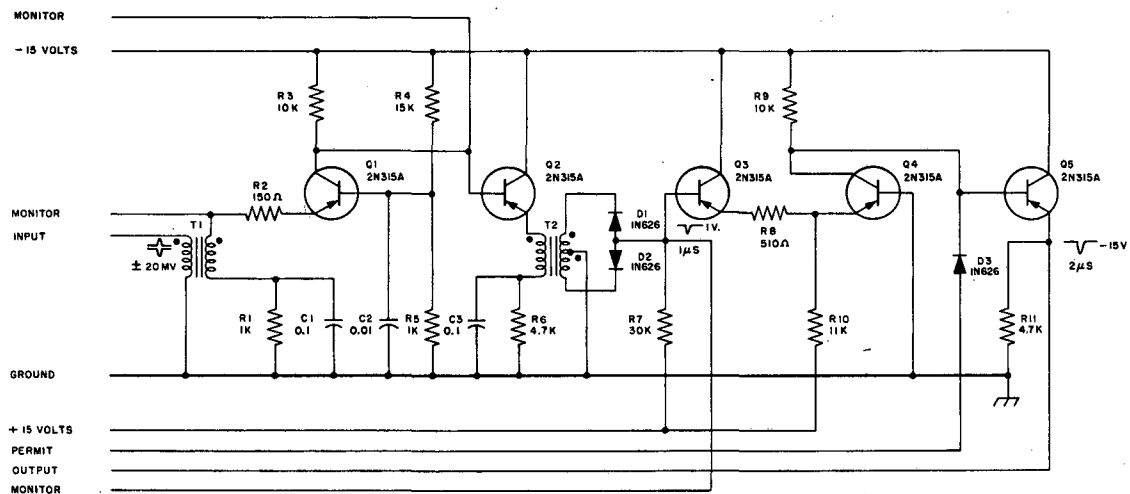
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Fig. 2.



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Fig. 3.



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Fig. 4.

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